Searching for Interstellar Pickup Ions in the Solar Wind using Cassini's Plasma Spectrometer

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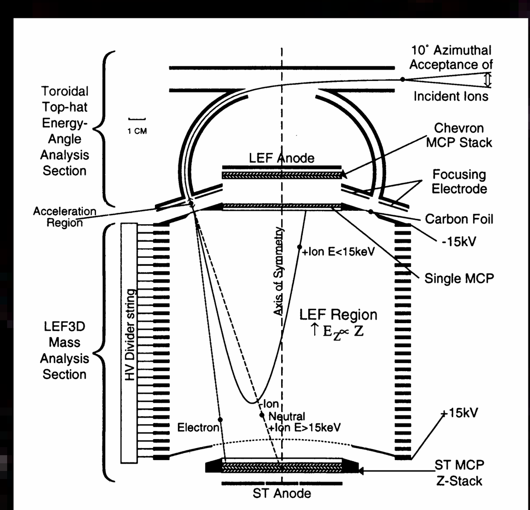
Introduction

Overview

Cassini's Ion Mass Spectrometer (IMS) is collecting solar wind data (mass per charge, energy per charge, direction, and number of ions) as it travels to Saturn. Interstellar Pickup Ions, photoionized gas from the Interstellar Medium (ISM), can be distinguished from solar ions by their velocity distribution. The project objective is to simplify Cassini data analysis by writing and using IDL programs to manipulate data, generate useful graphs, and identify the direction and number of Interstellar Pickup Ions.



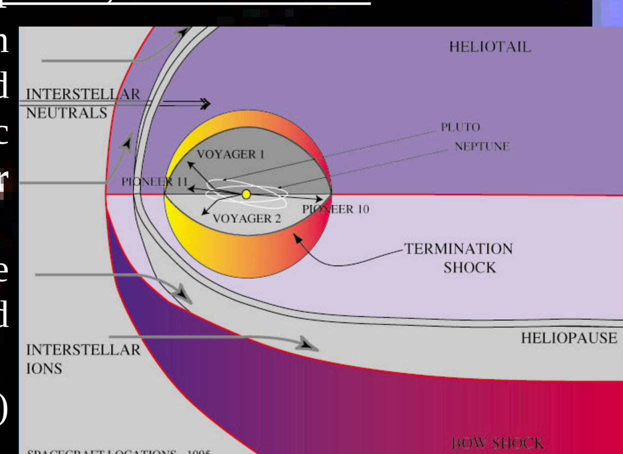
Drawing of IMS, courtesy Dr. Sittler

Cassini Ion Mass Spectrometer

- Developed by an international team with subsystem contributions from NASA's Goddard Space Flight Center
- Part of CAssini's Plasma Spectrometer or CAPS.
- Uses a unique electric field configuration and precise timing
- Can detect several species of ions
- Energy range: 1 eV - 50 keV.

The Solar Wind, the Heliosphere, and the ISM

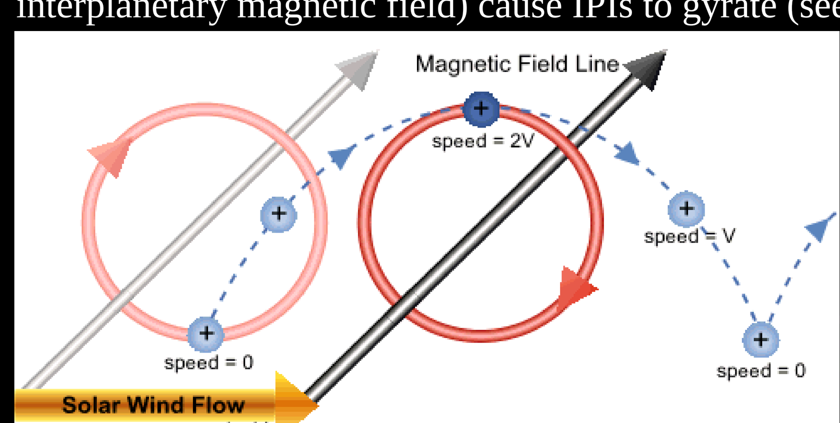
- The outer atmosphere of the sun fills the solar system charged particles traveling at supersonic speeds, collectively called the **solar wind**.
- Inside the **heliosphere**, the pressure from the solar wind dominates.
- The **Interstellar Medium** (ISM) is the gas and dust between stars.
- The sun traveling through the ISM (~25 km/s) causes neutral gas from the ISM to penetrate well into the solar system.



Interstellar neutrals entering the heliosphere

Interstellar Pickup Ions

- Interstellar neutrals are ionized near the sun and join the solar wind.
- Perpendicular electric and magnetic fields (from the solar wind and the interplanetary magnetic field) cause IPIs to gyrate (see diagram).

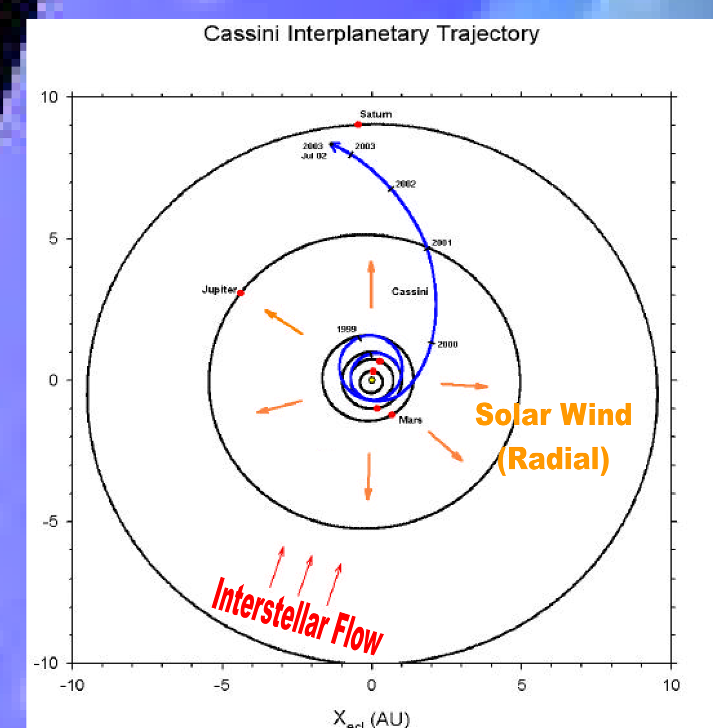


- Interstellar Pickup Ions travel between zero and two times the solar wind speed (see diagram).
- The number and direction of incident IPIs tell us about the ISM.

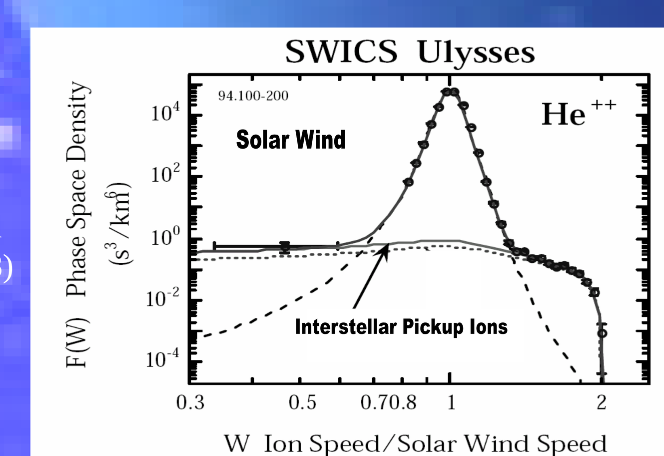
Personal Contributions

Background Research

- Literature Review
  - Understanding Cassini's location (see diagram below) and the IMS
  - Previous detection of IPIs: AMPTE's SULEICA and Ulysses' SWICS
  - Recognize signs in the data indicating IPIs
- Selected proton data for preliminary analysis (~10 days from 2001-02)



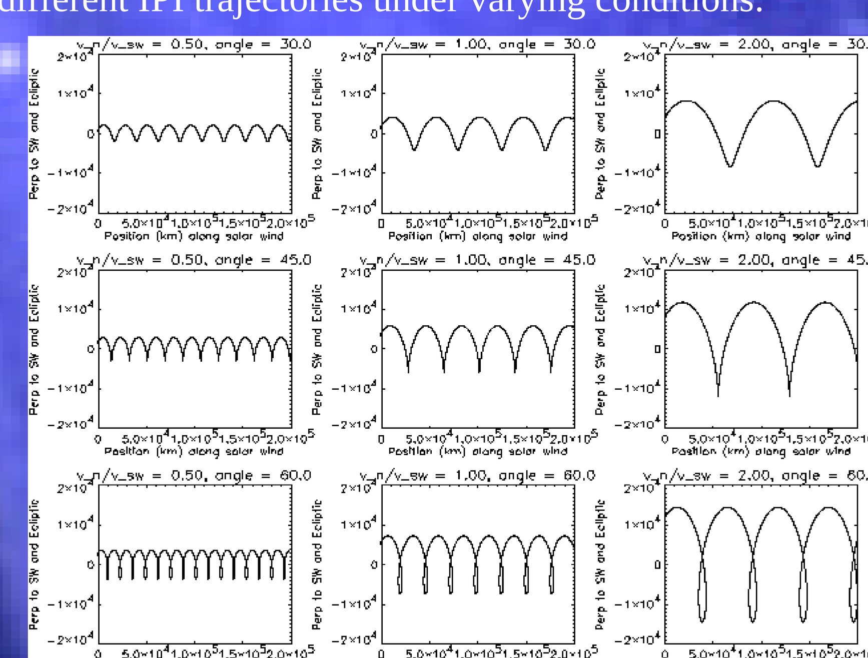
Cassini Interplanetary Trajectory and Interstellar Flow (courtesy David Simpson)



Phase Space Density vs. Ion Speed (modified, Gloeckler & Geiss, 1998)

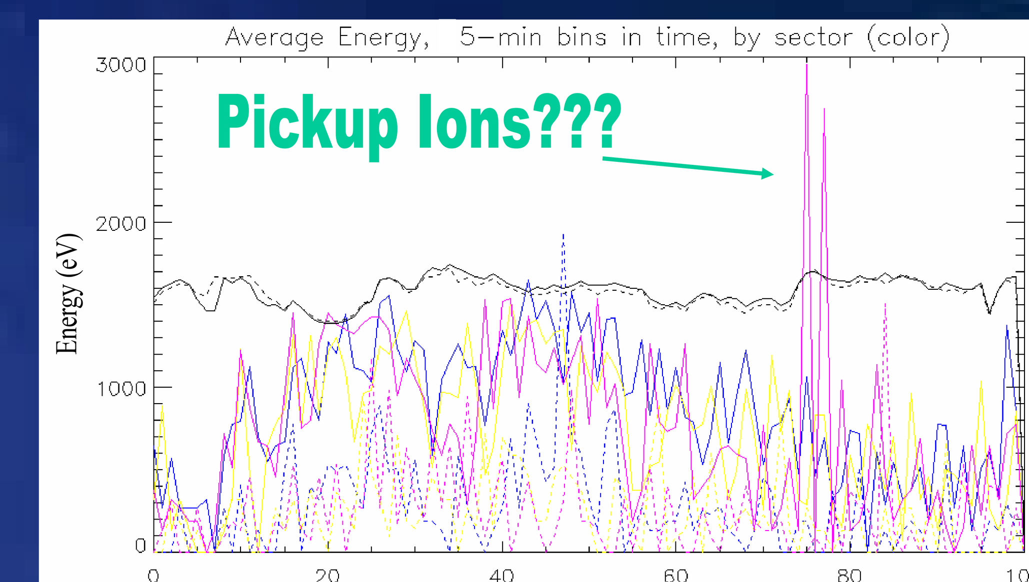
Predicting Ion Trajectories and Abundances

- Assumes a simple model:
  - constant solar wind velocity (electric field)
  - perpendicular magnetic field
- Used when determining the initial distribution of IPIs
- Gives different IPI trajectories under varying conditions:



Observations:

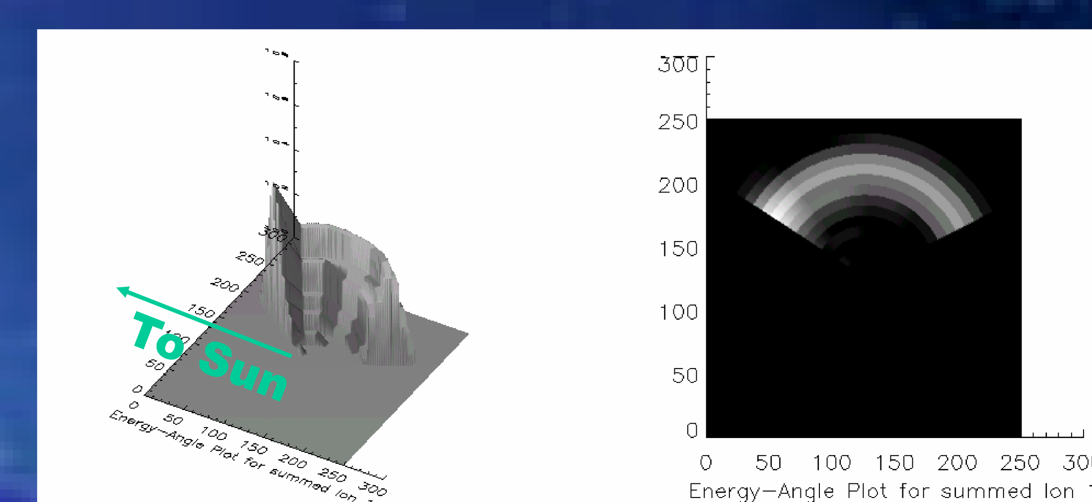
- Also generated graphs of time-changing average energy and instrument orientation (not shown)
- Necessary to understand the solar wind structure (energy and angle distribution, energy spectra, magnetometer data) to sort out the Interstellar Pickup Ions (possibly the two magenta peaks)

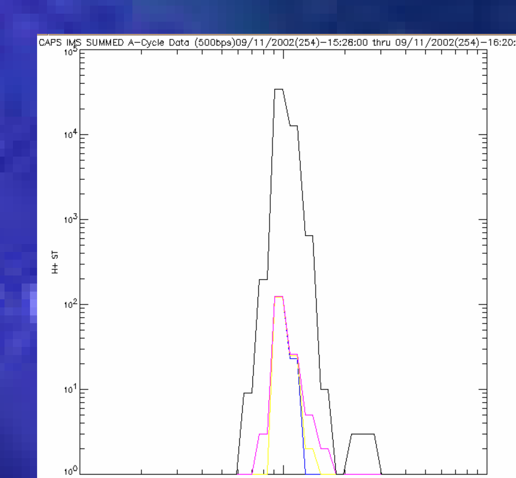


Binned Average Energy (eV) vs. Time (mins) for 09/11/02 proton data

Creating Programs in Interactive Data Language (IDL)

- Programs take raw "A-cycle" data files (32 seconds of observations), sum the data appropriately, and:
  - Generate index files for later use, increasing program efficiency and reducing computation time
  - Calculating the values of various parameters: average and standard deviation of velocity and energy, temperature, sound speed, etc.
  - Generate graphs of summed data: energy-angle phase diagrams (top, values on axes are arbitrary pixel values) and velocity dispersions (bottom, log-log plot).





IDL graphs of a heating event on 9/11/02, showing an unusually large velocity and angle dispersion.

Conclusions

Conclusions

- IDL programs effectively summarize Cassini IMS data, allowing for a deeper understanding of the solar wind intensity, velocity, and direction.
- Some data show instability, heating, and/or shocks making IPIs harder to identify and characterize.
- Interstellar Pickup Ions are very rare (as expected), and large amounts of data (~100 days) must be carefully summed.

Future Steps

- Expanding the capabilities of the IDL programs developed (higher bandwidths, more ions, more autonomous, etc.)
- Summing larger amounts of data (~100 days), sifting out Interstellar Pickup Ions, and plotting them in phase space
- Characterizing the number and shape (shell or ring) of the initial distribution of IPIs
- Refining current theories about the solar wind, ISM, and IPIs to match observations

References

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- http://www-ssg.sr.unh.edu/tof/Outreach/Interstellar/index.html
- Background image of termination shock, heliopause, and bow shock from Hanson and Frisch, © Indiana University.

Acknowledgements

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